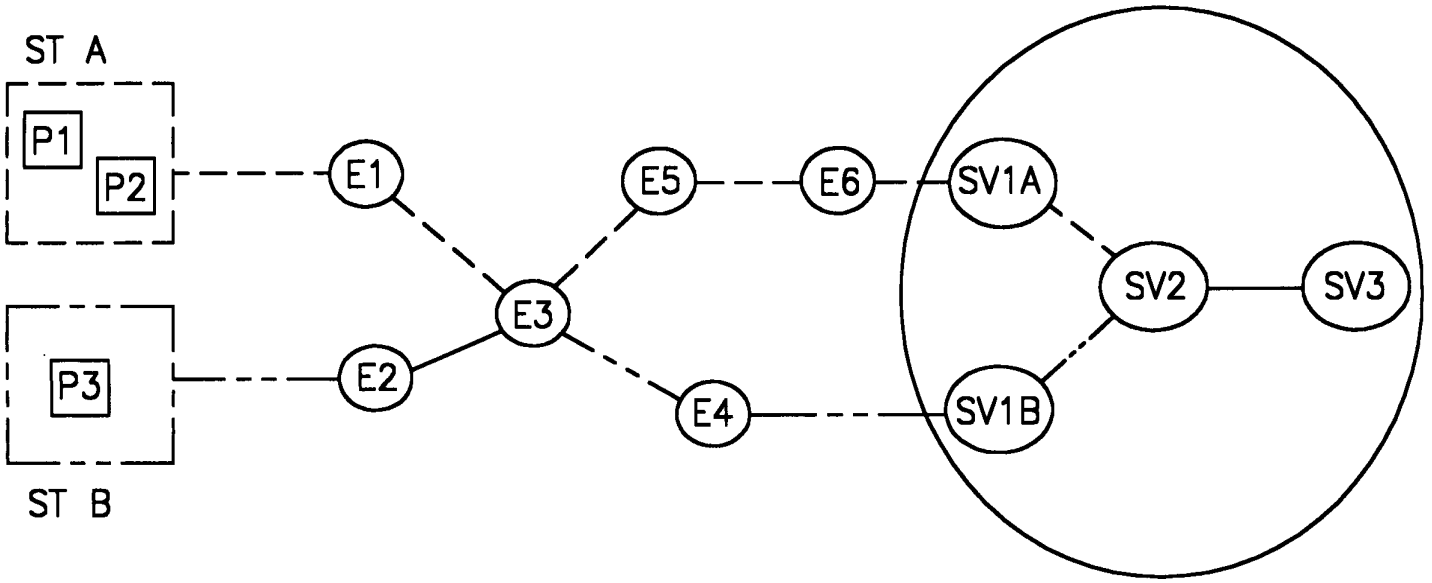
PROBING TECHNOLOGY

PROBES = TEST TRANSACTIONS (E.G.,PING, TRACEROUTE, MAIL– OR WEB–ACCESS)



ST – PROBE STATION
P – PROBE
E – ELEMENT
SV – SERVICE

FIG. 1

EXAMPLE

A SINGLE PROBE

N_1 N_2 N_3 N_4 N_5 N_6

P_{15} 1 1 0 0 1 0

P_{15} FAIL =>PROBLEM WITH

{ N_1, N_2, N_5 }

P_{15} OK =>PROBLEM WITH

{ N_3, N_4, N_6 } OR NO PROBLEM

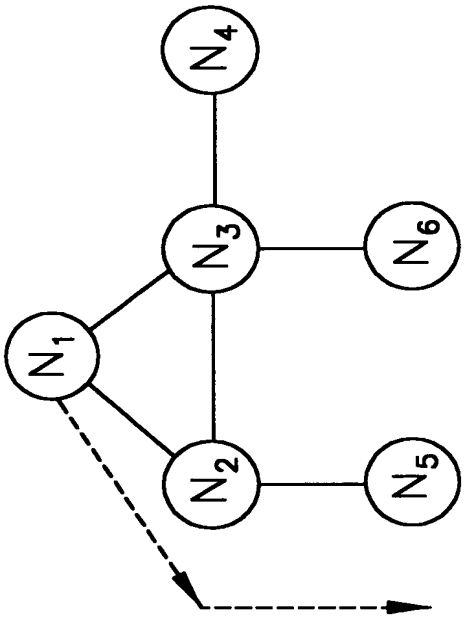


FIG. 2

EXAMPLE

TWO PROBES – A DEPENDENCY MATRIX
r=NUMBER OF PROBES, n=NUMBER OF NODES

DEPENDENCY MATRIX (rxn)

	N_1	N_2	N_3	N_4	N_5	N_6
P_{15}	1	1	0	0	1	0
P_{16}	1	0	1	0	0	1

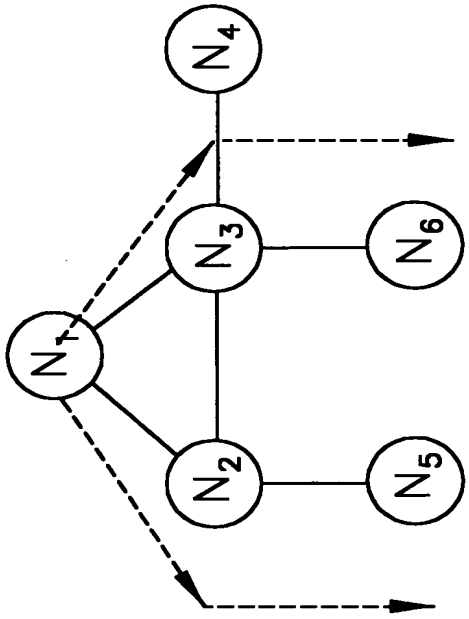


FIG. 3

EXAMPLE

PROBE SIGNALS AND DIAGNOSABLE PROBLEMS

"DIAGNOSABLE PROBLEMS" ARE {{N_1},{N_2,N_5},{N_3,N_6},{N_4, NONE}}

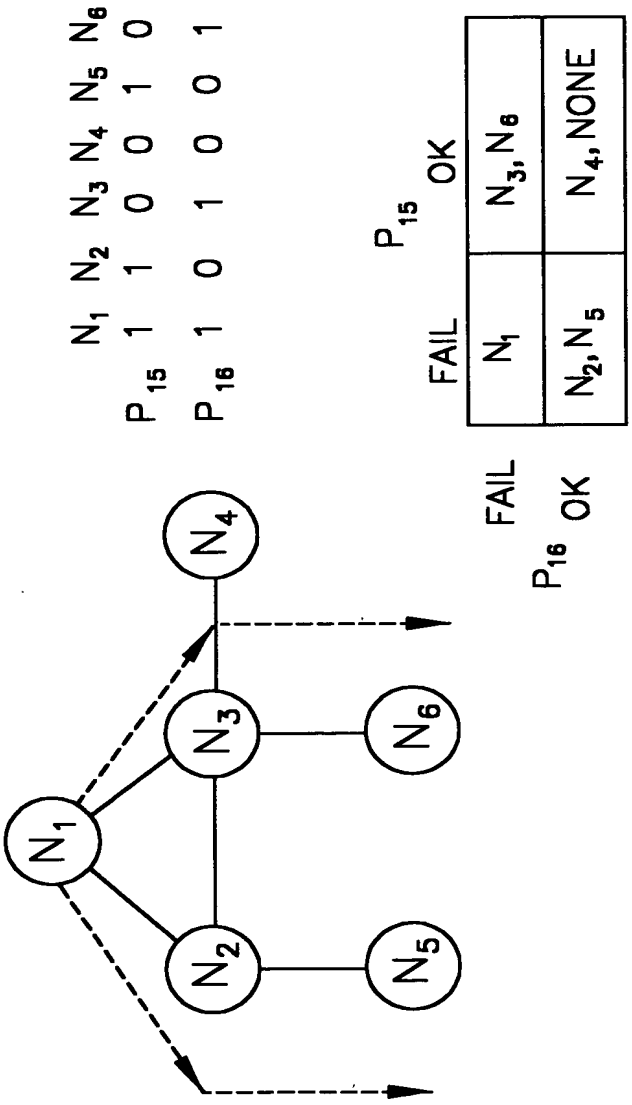
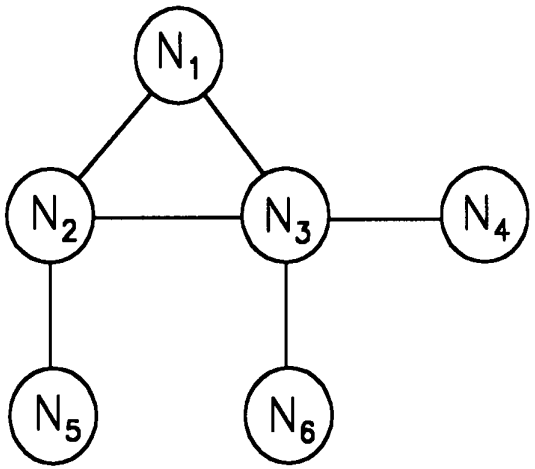


FIG. 4

DIAGNOSING ANY FAILURE

ALL PROBLEMS DIAGNOSED BY 3 PROBES

DIAGNOSABLE PROBLEMS ARE $\{\{N_1\},\{N_2\},\{N_3\},\{N_4\},\{N_5\},\{N_6\},\{\text{"NONE"}\}\}$



	N_1	N_2	N_3	N_4	N_5	N_6
P_{15}	1	1	0	0	1	0
P_{16}	1	0	1	0	0	1
P_{42}	0	1	1	1	0	0

N_1 AND N_4 ARE PROBE–STATIONS

FIG. 5

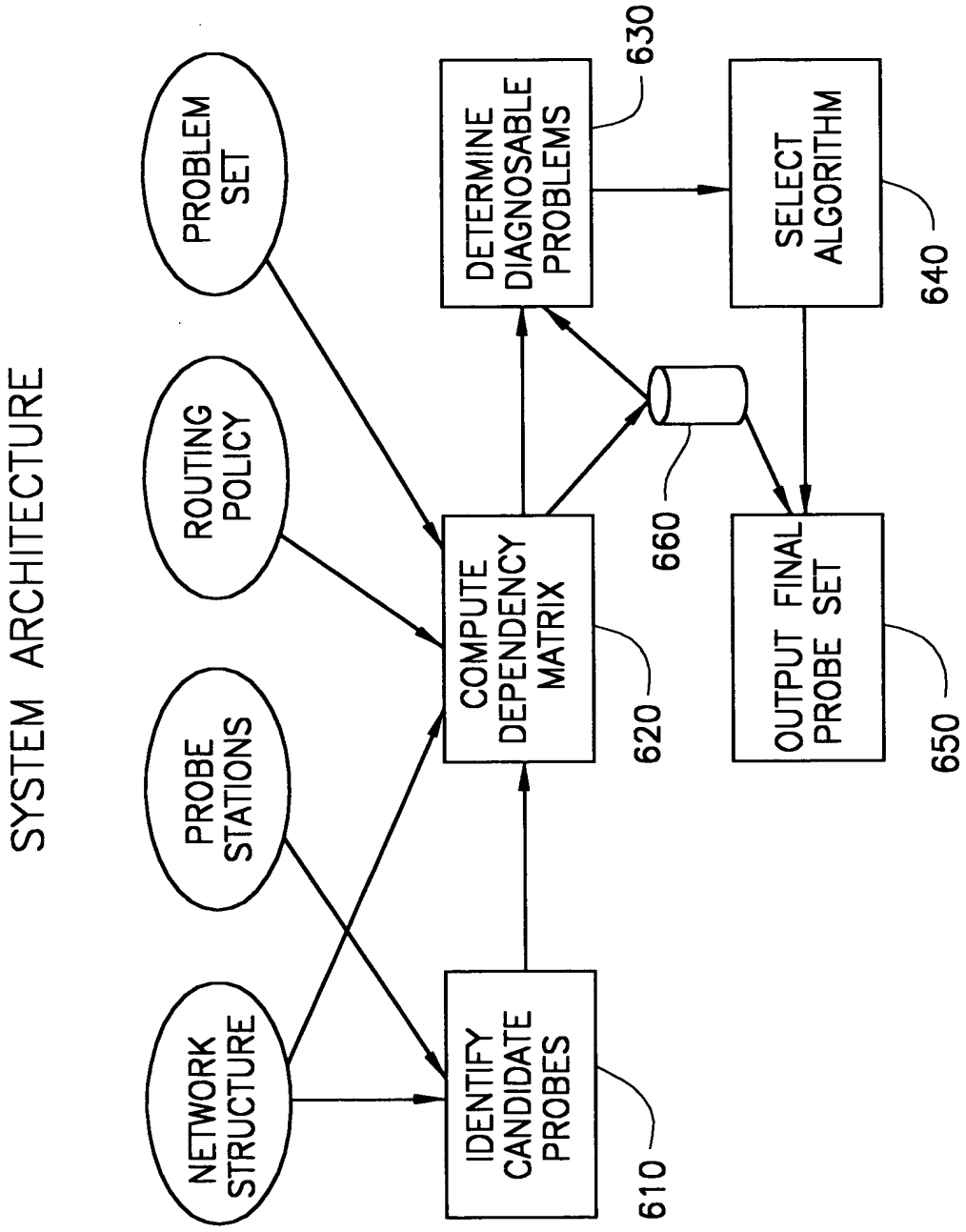

SYSTEM ARCHITECTURE
PROBLEM SET
ROUTING POLICY
PROBE STATIONS
NETWORK STRUCTURE
DETERMINE DIAGNOSABLE PROBLEMS
630
SELECT ALGORITHM
640
COMPUTE DEPENDENCY MATRIX
620
660
OUTPUT FINAL PROBE SET
650
IDENTIFY CANDIDATE PROBES
610

FIG. 6

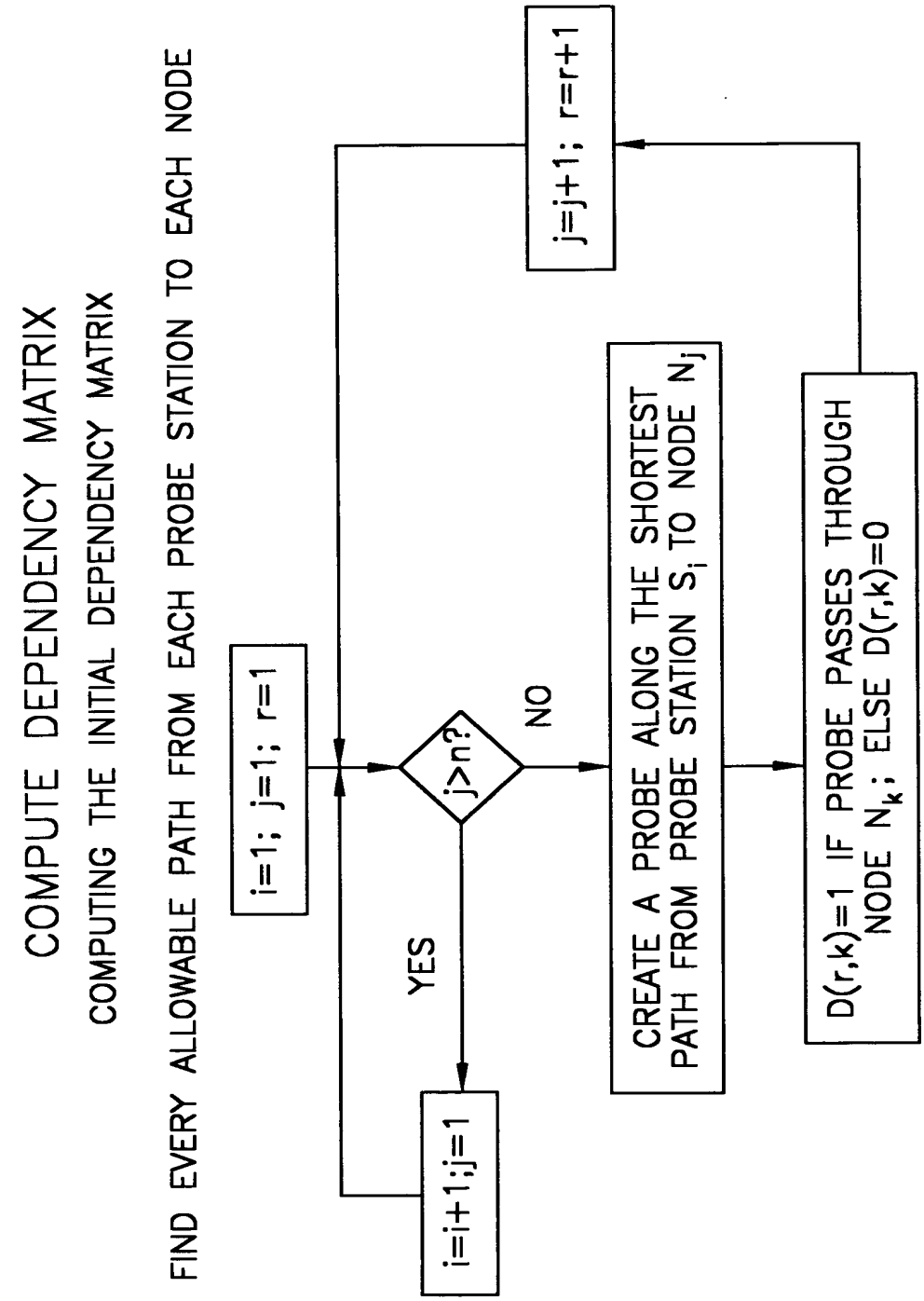
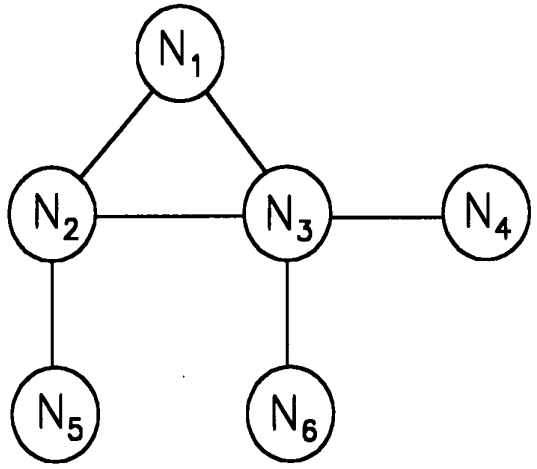

COMPUTE DEPENDENCY MATRIX
COMPUTING THE INITIAL DEPENDENCY MATRIX
FIND EVERY ALLOWABLE PATH FROM EACH PROBE STATION TO EACH NODE
i=1; j=1; r=1
j>n?
YES
NO
i=i+1;j=1
CREATE A PROBE ALONG THE SHORTEST PATH FROM PROBE STATION S_i TO NODE N_j
D(r,k)=1 IF PROBE PASSES THROUGH NODE N_k; ELSE D(r,k)=0
j=j+1; r=r+1

FIG. 7

INITIAL DEPENDENCY MATRIX

AN EXAMPLE OF THE INITIAL DEPENDENCY MATRIX N_1 AND N_4 ARE PROBE–STATIONS – THERE IS ONE PROBE FROM EACH PROBE–STATION TO EACH NODE, FOLLOWING SHORTEST PATH ROUTING.



DEPENDENCY MATRIX (rxn)

	N_1	N_2	N_3	N_4	N_5	N_6	NF
P_{12}	1	1	0	0	0	0	0
P_{13}	1	0	1	0	0	0	0
P_{14}	1	0	1	1	0	0	0
P_{15}	1	1	0	0	1	0	0
P_{16}	1	0	1	0	0	1	0
P_{42}	0	1	1	1	0	0	0
P_{43}	0	0	1	1	0	0	0
P_{45}	0	1	1	1	1	0	0
P_{46}	0	0	1	1	0	1	0

FIG. 8

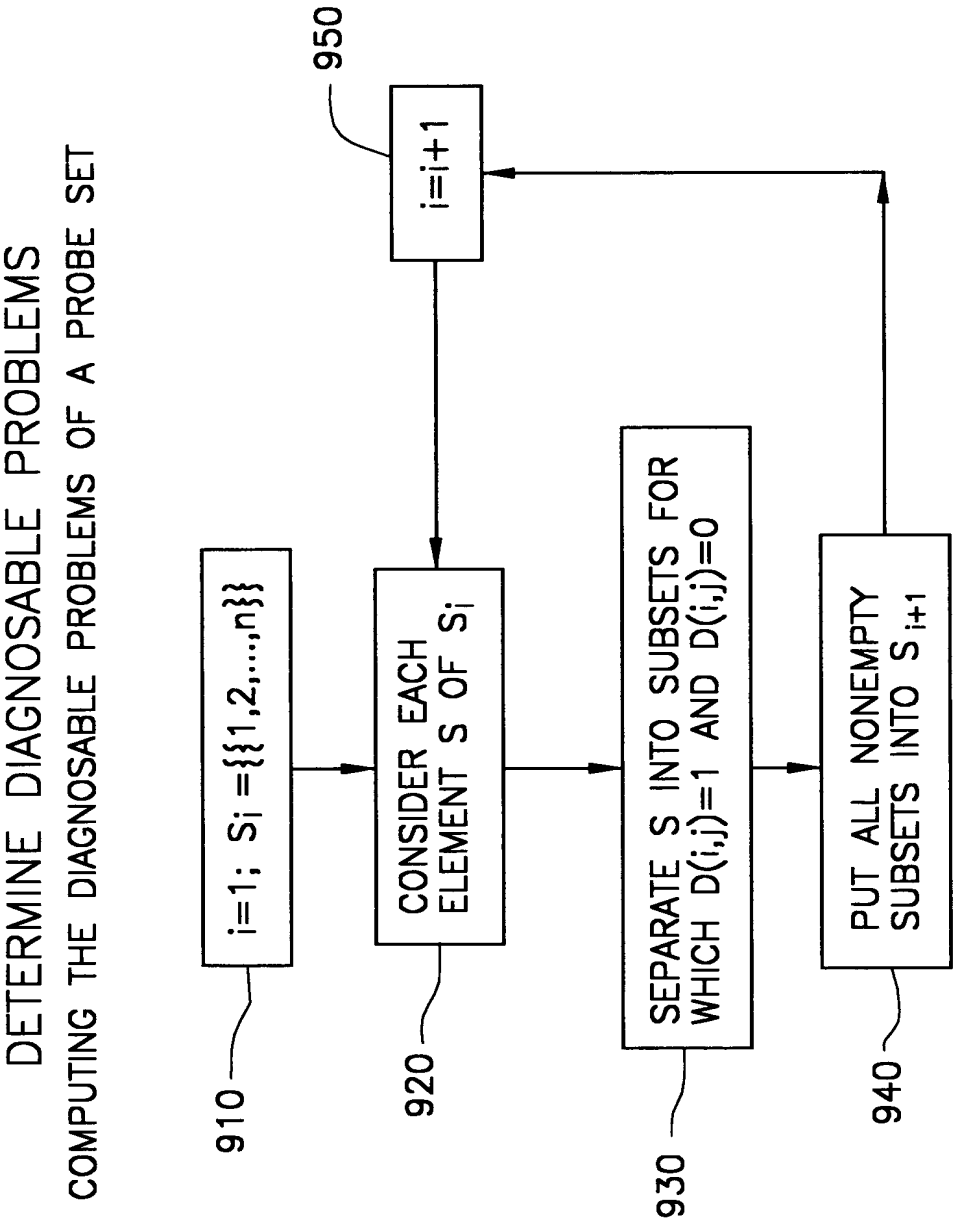

DETERMINE DIAGNOSABLE PROBLEMS
COMPUTING THE DIAGNOSABLE PROBLEMS OF A PROBE SET
i=1; Si ={{1,2,...,n}}
CONSIDER EACH ELEMENT S OF Si
SEPARATE S INTO SUBSETS FOR WHICH D(i,j)=1 AND D(i,j)=0
PUT ALL NONEMPTY SUBSETS INTO Si+1
i=i+1
910
920
930
940
950

FIG. 9

EXAMPLE

AN EXAMPLE OF COMPUTING THE DIAGNOSABLE PROBLEMS OF A GIVEN PROBE SET

(0) $S_0 = \{\{N_1, N_2, N_3, N_4, N_5, N_6, NF\}\}$

(1)

	N_1	N_2	N_3	N_4	N_5	N_6	NF
P_{15}	1	1	0	0	1	0	0

$S_1 = \{\{N_1, N_2, N_5\}, \{N_3, N_4, N_6, NF\}\}$

(2)

	N_1	N_2	N_3	N_4	N_5	N_6	NF
P_{16}	1	0	1	0	0	1	0

$S_2 = \{\{N_1\}, \{N_2, N_5\}, \{N_3, N_6\}, \{N_4, NF\}\}$

(3)

	N_1	N_2	N_3	N_4	N_5	N_6	NF
P_{42}	0	1	1	1	0	0	0

$S_3 = \{\{N_1\}, \{N_2\}, \{N_3\}, \{N_4\}, \{N_5\}, \{N_6\}, \{NF\}\}$

FIG. 10

EXHAUSTIVE SEARCH

EXHAUSTIVE SEARCH TO FIND THE MINIMAL PROBE SET

PROBES THRU(j)=ALL PROBES PASSING THROUGH N_j.

AxB=ALL SETS CONTAINING ONE ELEMENT FROM A AND A DISTINCT ELEMENTFORM B

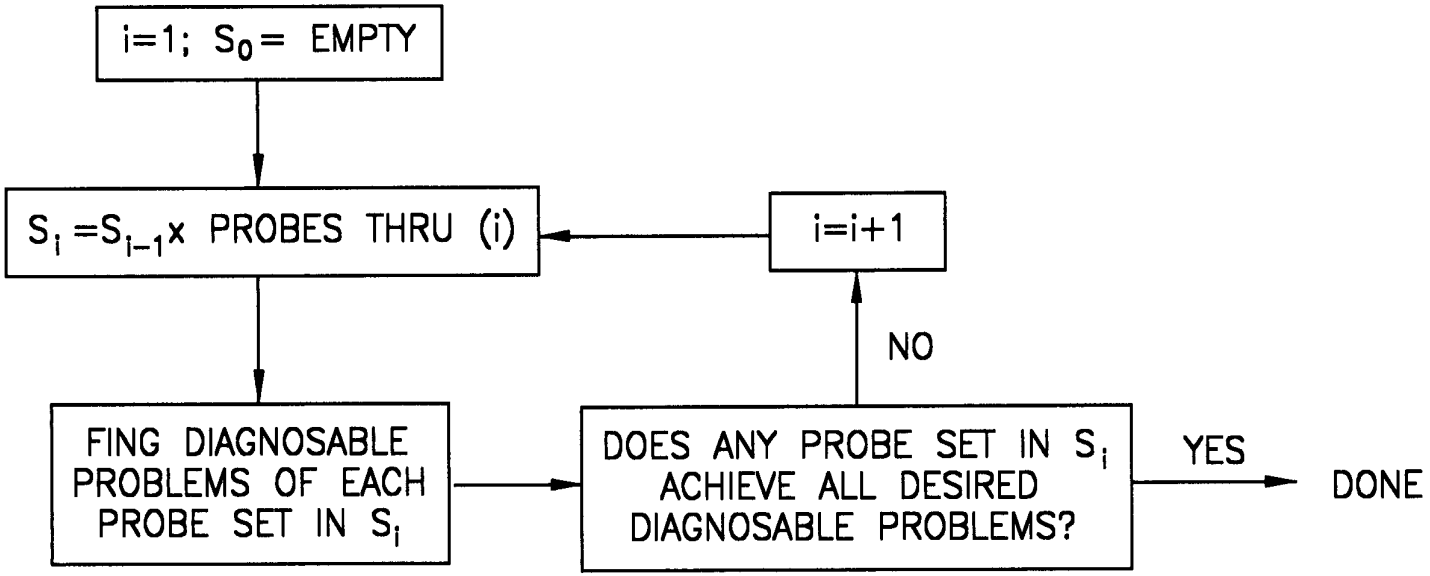


FIG. 11

QUICK SEARCH

QUICK SEARCH TO FIND A SMALL PROBE SET

IDEA: THROW AWAY PROBES THAT ARE NOT NEEDED

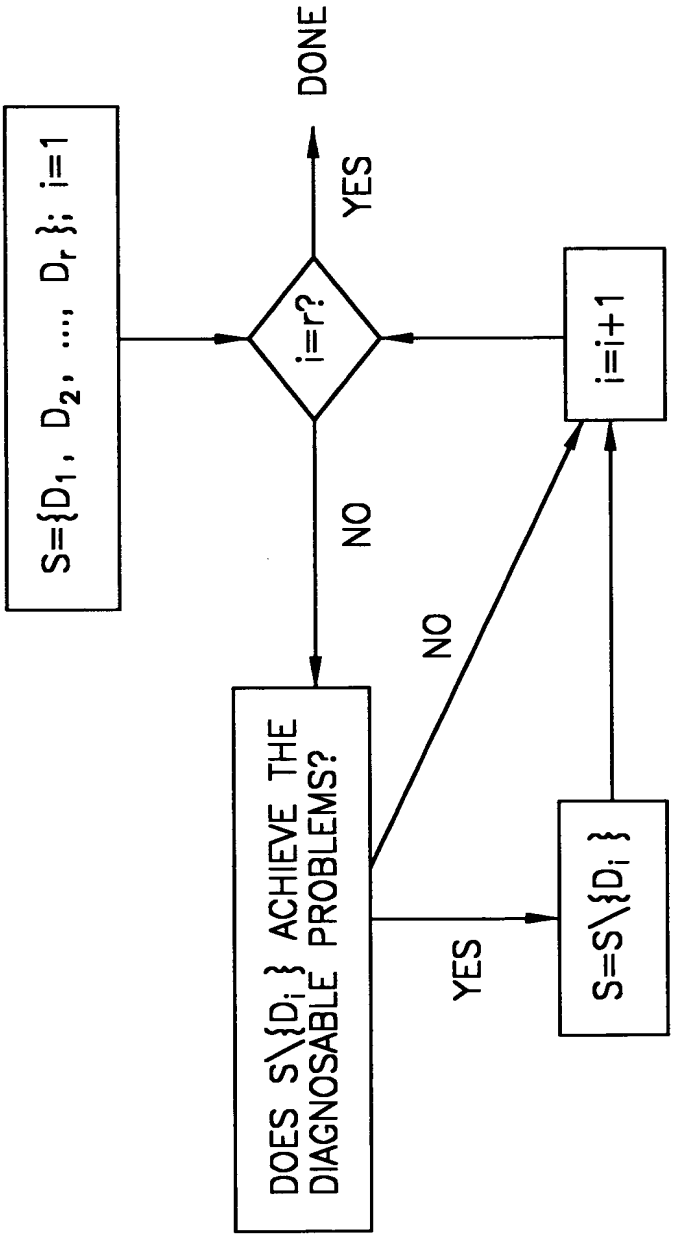


FIG. 12

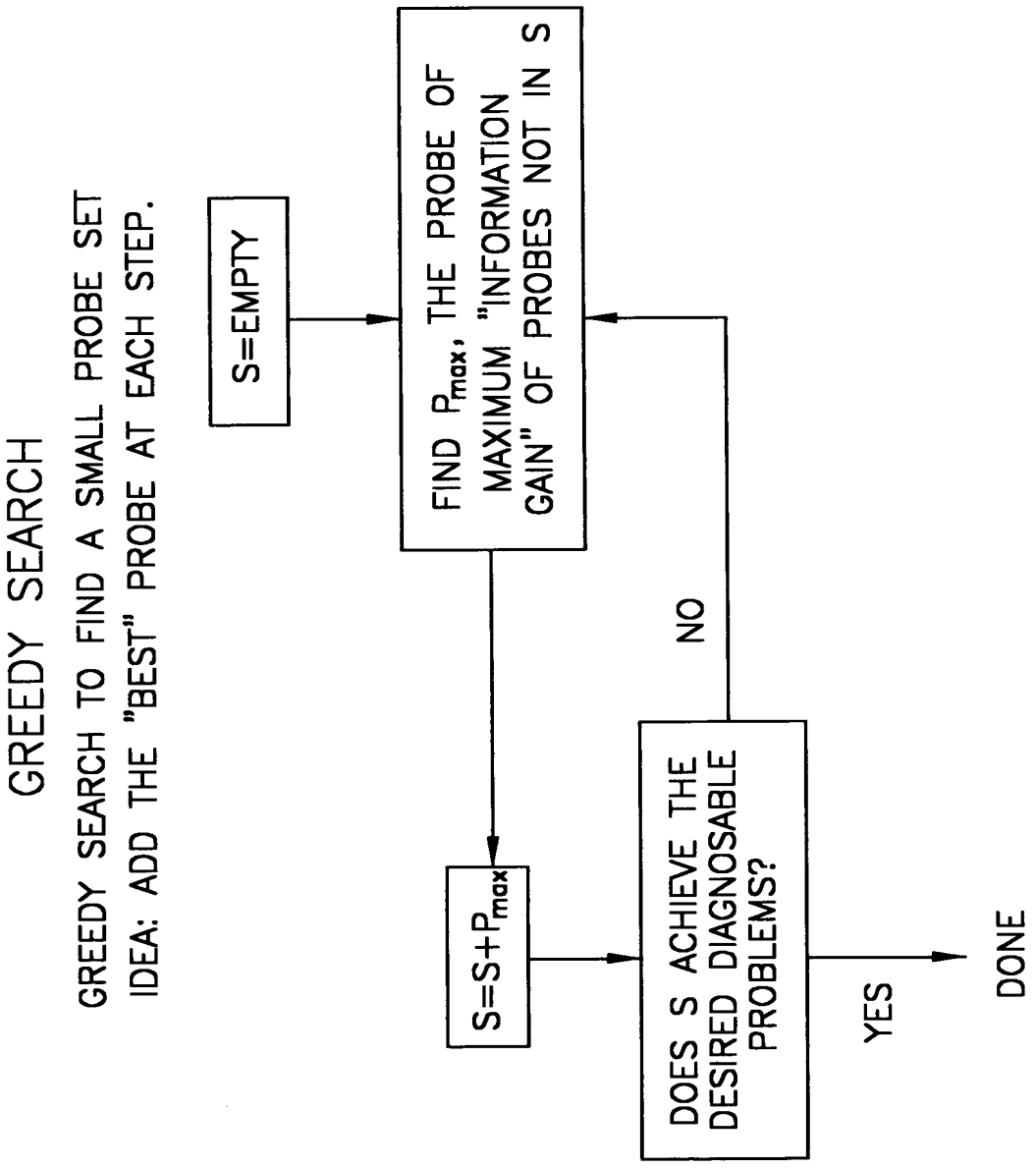

GREEDY SEARCH
GREEDY SEARCH TO FIND A SMALL PROBE SET
IDEA: ADD THE "BEST" PROBE AT EACH STEP.
S=EMPTY
FIND P_{max}, THE PROBE OF MAXIMUM "INFORMATION GAIN" OF PROBES NOT IN S
$S=S+P_{max}$
DOES S ACHIEVE THE DESIRED DIAGNOSABLE PROBLEMS?
NO
YES
DONE

FIG. 13